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FIELD TRIALS OF A RAPID SEQUENTIAL TRACER GAS ANALYZER

A.W. Stokes and S.G. Hardcastle

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by

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SUMMARY

Tracer gas is finding an increasing number of applications to aid the solution of complex mine ventilation problems. The Cape Breton Coal Research Laboratory is trying to make tracer gas a more versatile tool by developing an instrument capable of measuring it in real-time suitable for underground coal mining environments. This report describes the field trial of a prototype instrument which was used in the uranium mines of Elliot Lake, Ontario. The trial was conducted in cooperation with Elliot Lake Mining Research Laboratory personnel who were interested in obtaining ventilation data to verify theoretical relationships about stope residence times. Details of the techniques which were used and the results obtained are given together with an assessment of the instrument's performance for this application.

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ESSAIS SUR LE TERRAIN D'UN ANALYSEUR SÉQUENTIEL RAPIDE DE GAZ TRACEURS

par

A.W. Stokes* et S.G. Hardcastle**

RÉSUMÉ

Les techniques à gaz traceur s'appliquent à un nombre toujours croissant d'usages visant à résoudre les problèmes complexes de la ventilation dans les mines souterraines. Le Laboratoire de recherche sur le charbon du Cap-Breton essai de transformer les techniques à gaz traceur en un outil à usages variés, en mettant au point un instrument capable de mesurer le gaz traceur en temps réel approprié au milieu des mines de charbon souterraines. Ce rapport présente donc une description des essais sur le terrain du prototype d'un tel appareil qui a été utilisé dans les mines d'uranium d'Elliot Lake en Ontario. Les essais ont été menés en collaboration avec le personnel des Laboratoires de recherche minière à Elliot Lake. Ces derniers étaient, en outre, intéressés d'obtenir des données d'essais sur la ventilation afin de vérifier les relations théoriques des temps de séjour dans les chantiers d'abattage. Les détails des techniques utilisées et les résultats d'essais obtenus sont présentés ensemble avec un compte rendu du rendement de l'appareil lors de ces essais.

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INTRODUCTION

The Cape Breton Coal Research Laboratory (CBCRL) is actively investigating the use of tracer gases for solving mine ventilation and related problems. To date, several studies have been completed using sulphur hexafluoride (SF_6) and propane (C_3H_8) as tracer gases. Propane was used to investigate the ventilation system of a full face tunnel boring machine (TBM) on the surface prior to the machine being used underground. A flame ionisation detector was used with a total hydrocarbon analyser to obtain a real-time detection in the cutting head exhaust airstream. This type of analysis proved very flexible and allowed a good evaluation of the TBM's ventilation system (1). Propane could not be used in an underground coal mine due to the presence of other hydrocarbons, such as methane, and permissibility problems with the detection equipment.

Most work with tracer gases in coal mines has so far been limited to using either SF_6 or nitrous oxide (N_2O) as the tracer gas. These are collected as grab samples from underground and analysed on surface using a gas chromatograph. The grab sampling technique is adequate for most uses of SF_6, but the ability to measure in real-time underground would open up several new uses and generally improve the versatility of SF_6 as a ventilation tool. CBCRL is presently investigating ways of achieving this aim.

There are many difficulties encountered when measuring SF_6 on a real-time basis in a permissible environment; these are compounded in the underground coal mine environment. CBCRL has taken an intermediate step before building a true real-time instrument of developing a unit that can analyze a sample once every 10 seconds. This prototype instrument in its present form would not pass the ridgid certification requirements for use in an hazardous underground environment, but with some modifications could be made to comply. Before going through the procedures to do this, it was decided to determine the instrument's performance in a harsh underground environment. A non-inflammable gaseous uranium mine owned by Rio Algom Ltd. in Elliot Lake was selected, as this offered the chance on combining the field test with a research programme being conducted by the underground environment research group of CANMET's Elliot Lake Mining Research Laboratory. The laboratory also provided servicing facilities and a base from which to work.

Elliot Lake researchers have been investigating the radon gas emissions from mined out stopes for sometime. From their work they have developed a number of theoretical relationships describing the decay of the gas into the daughters of radon (2). These equations are very dependant on residence time and therefore, also the ventilation flow rates through the stopes. To date, very little has been done about accurately measuring these parameters. A series of cooperative studies were planned between the two groups which included a number of tests to measure the airflow and residence times in a large mined out stope. This allowed both groups to achieve their objectives: field testing of the instrument and accurate measurement of fundamental ventilation parameters with which to truth the theoretical relationships.

OBJECTIVES

The main objective of the field trials was to assess the performance of the instrument in a harsh underground environment over a period of several days. The operational difficulties experienced were of particular interest as these would identify any necessary modifications that need to be made to the instrument before undertaking the certification procedure.

The secondary objective was to determine the relationship between the airflow through the stope and its residence time inside. For a regular shaped stope with no large volume obscured from the main airflow paths the residence time should be directly proportional to the volume flow rate of the ventilation. This can be easily verified by a series of tracer gas injections. Additional information which can be gained from the injections include: measuring the volume of the stope, comparing the techniques of pulse injections of tracer gas with a continuous injection and an evaluation of automated ventilation recorders recently purchased by ELMRL.

STOPE RESIDENCE TIME INVESTIGATIONS

DESCRIPTION OF THE TEST SITE

The residence time determinations were performed in a stope, Stope 8260, in an old working area of one of Rio Algom's uranium mines. There was no active production in close proximity as the stopes in the area

were undergoing leaching. This was advantageous as it meant that variations and sudden fluctuations in the airflow were minimal.

Stope 8260 is a large open stope approximately 381 m long, 16.5 m wide and 3.9 m high with a trapezoidal cross-sectional shape. The roof is supported by a series of rock pillars left at regular intervals along the centreline of the stope. The overall condition of the stope was good with only a small amount of spauling from the roof end walls, none of which was enough to cause a significant disruption to the airflow through the stope.

Figure 1 shows a map of the area of the mine close to Stope 8260. There are six stopes parallel to Stope 8260, each draws air from an intake drive via narrow openings of a few square metres cross-section area. Wooden regulators have been built into the openings which can be varied to provide an open area ranging from 0.53 m^2 to being completely closed. Air is discharged from the stopes into the return drivage. Access through the stopes was impossible as they were partially flooded for leaching purposes. Instead access was via a ramp which runs adjacent to Stope 8260 and a crosscut which joins it to the return drivage. The crosscut had double air lock doors installed.

Prior to the start of the survey all the stope regulators were closed and made as airtight as possible forcing most of the air from the intake level to pass through a regulator at the end of the drivage. This setup helped maintain a stable airflow through Stope 8260 for the duration of the experiments.

The gas chromatograph was located at the outlet of Stope 8260. The instrument was placed inside a protective cage and left running for the duration of the experiment. The cage was situated inside the stope itself so that samples could be drawn from the ambient air reducing the risk of dilution of fresh air passing by the outlet.

EXPERIMENTAL PROTOCOL

All the airflow measurements were made by injecting SF_6 into the inlet of the stope and measuring resultant concentrations at the outlet. Over a four-day period a total of six measurements were made. The first was achieved using a continuous injection of SF_6 and the remaining five by pulse injections. Each measurement was for a different setting of the stope regulator as shown in Table 1.

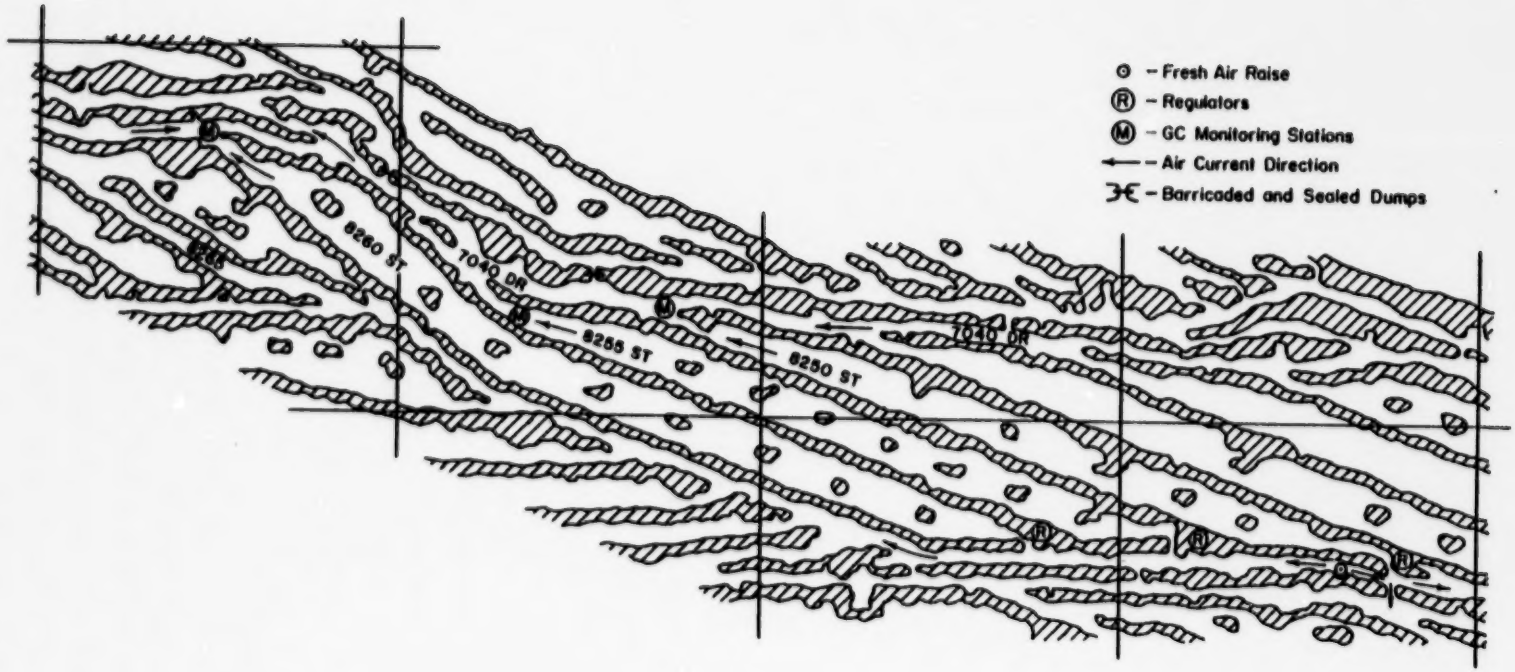

Figure 1 - Plan of the test Stope 8260 and surrounding area

Table 1 - Schedule of airflow and residence time measurements in Stope 8260

Open Area of the Regulator (m^2)	Date and Time of Injection	Type of Injection and Volume
0.525	Monday 18 - 0932 hr	Continuous
	- 1122 hr	(4.59 cc/min)
0.525	Monday 18 - 1207 hr	Pulse (150 cc)
0.132	Tuesday 19 - 0814 hr	Pulse (100 cc)
0.262	Tuesday 19 - 1103 hr	Pulse (150 cc)
0.034	Wednesday 20 - 0808 hr	Pulse (150 cc)
0.394	Thursday 21	Pulse (150 cc)

The Continuous Injection

The continuous injection lasted for more than 2 hours. This allowed the airflow through the stope to be determined and also provided an indication of its stability during the 2-hour period.

A continuous steady flow rate of SF_6 was obtained from a lecture bottle of the gas with a limiting orifice connected to the bottle regulator. This was placed in the regulator opening of the stope where the high air velocities ensured a good dispersion of the gas into the airstream. At the beginning and end of the injection, just after opening and prior to the closing of the regulator valve, the tracer gas flow rate was measured with a soap bubble flow meter. This value is needed to calculate the volume flow of air through the stope from the following equation:

$$Q = \frac{\dot{v}}{c} \qquad \text{Eq 1}$$

where Q is the airflow through the stope (m^3/s)

$\dot{v}$ is the flow rate of the tracer gas (m^3/s)

and c is the concentration of the tracer gas measured in the airstream at the outlet of the stope (ppb.s)

The Pulse Injections

All subsequent measurements were made using pulse injections. These provided values of the airflows and residence times, and were easier and quicker to perform than the continuous injection.

The pulse injections were released into the airsteam from plastic syringes filled with a precise volume of tracer gas (either 100 or 150 ml). So as to avoid contamination of the air in the stope, the syringes were filled in a return airstream on the other side of the lower level regulator. They were sealed, taken to the stope inlet and injected into the regulator opening at the appropriate time.

For this type of injection the volume flow rate of the air moving through the stope is calculated from the following relationship:

$$Q = \frac{v}{c\tau} \qquad \text{Eq 2}$$

where v is the volume of tracer gas released (m^3)

and $c\tau$ is area under the concentration of tracer gas/time curve measured at the outlet of the stope (ppb.s)

The resultant tracer gas concentrations in the exhaust airstream were measured with the prototype gas chromatograph. This was located at the outlet of Stope 8260 inside a protective cage. The instrument was placed in the exhaust airstream to eliminate the need to draw an air sample to the analysis site with the inherent risk of sample contamination.

Measurement and Recording Stope Outlet SF_6 Concentrations

A detailed description of the instrument which was used to measure the ambient SF_6 concentrations is given elsewhere (3). Briefly, the instrument comprises a gas sampling pump which continuously draws air through a sampling loop. Air is injected from the sampling loop, alternately, into two molecular sieve columns every 10 seconds. The molecular sieve columns separate the SF_6 from the other components of the gaseous mixture and once it has been eluted the remaining gases are backflushed. The volume flow of the carrier gas is set such that both the separation and backflushing cycles takes less than ten seconds. This allows each of the two operations to take

place in both columns simultaneously; this increases the throughput of samples into the detector.

The SF_6 is measured by a sensitive electron capture detector which produces an output voltage proportional to the concentration. The output voltage is logged on a stip chart recorder producing a concentration versus time plot which can be interpreted onsite (the onsite analysis is useful as it allows trouble shooting to be done in the mine).

All activities occurring at the two ends of the stope were coordinated by synchronised digital stop watches. This was necessary to determine the residence time of the SF_6 in the stope.

RESULTS

The resultant tracer gas concentrations recorded at the stope outlet were digitised and stored in a computer to allow better data manipulation and comparison. Figure 2 shows a reduced copy of the actual concentration versus time chart recorded underground for the continuous injection. The analysis rate had been slowed down for this injection to one analysis every 15 seconds. Timing marks are marked onto the top of the charts and also the time at which the gas was shut off.

RESULTS OF CONTINUOUS INJECTION

The Stability of the Airflow

The tracer gas concentration is given by the height of the peak from the baseline (marked on Figure 2). The two columns used in the instrument had slightly different calibrations which accounts for the difference in the height of adjacent peaks during the period of steady state exhaust concentrations. This calibration anomoly was compensated for in the other injections after the data was entered into the computer.

The regulator of the lecture bottle was opened at 0932 hrs. The timing marks showed that SF_6 was first detected in the outlet airstream at 1020 hrs, 48 minutes later. This represents the fastest airstream in the stope which had a longitudinal velocity of 0.13 $m.s^{-1}$. The SF_6 concentration increased until a steady state concentration of 10.6 ppb was achieved at

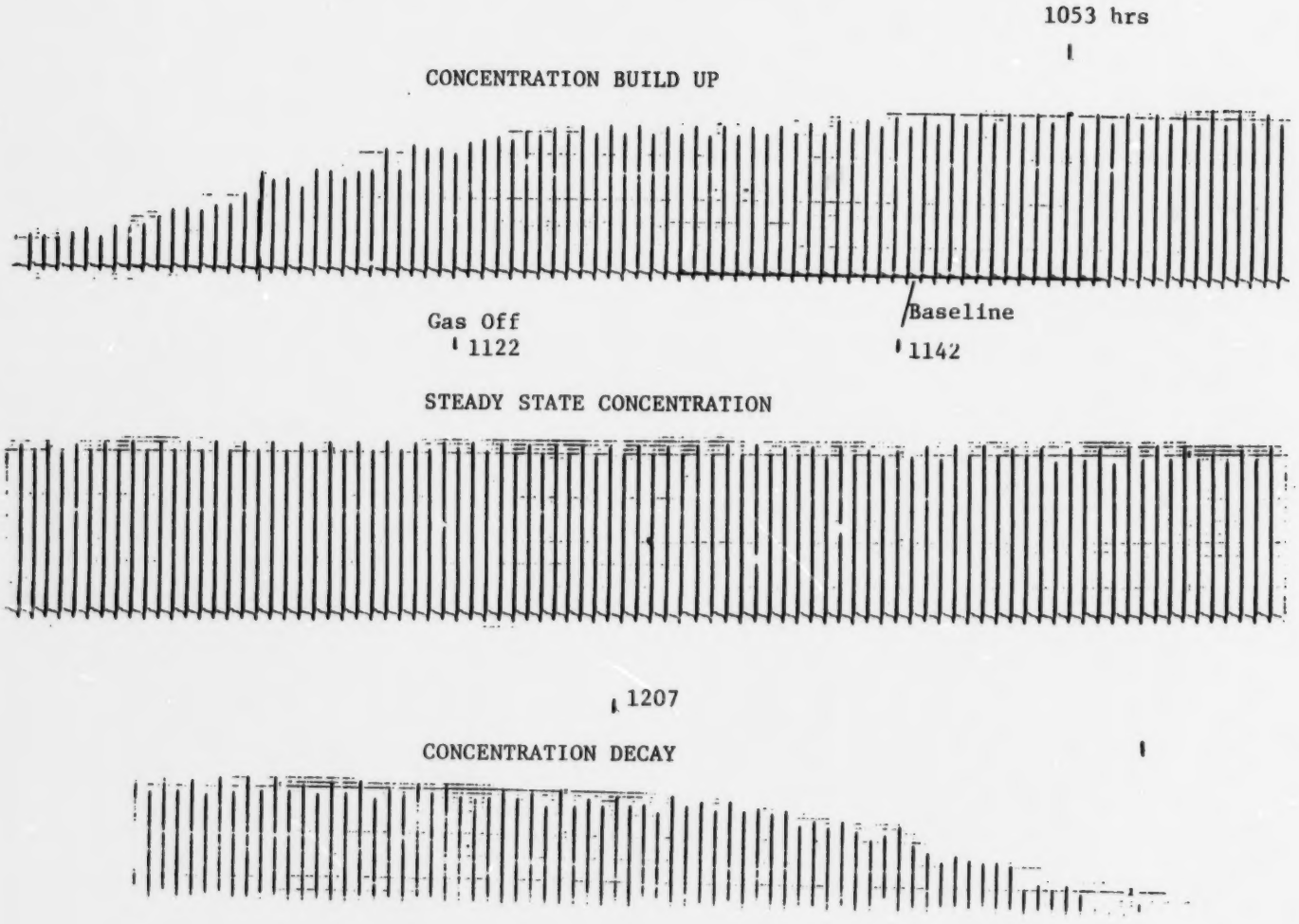

Figure 2 - Chromatogram of the continuous injection into Stope 8260

about 1053 hrs (it is hard to determine the exact moment that steady state in the outlet concentration was attained), 93 minutes after the initial release.

The SF_6 was allowed to flow into the stope until 1122 hrs when it was removed from the inlet and the cylinder regulator closed (if the regulator had been closed and the lecture bottle left in the stope, SF_6 would have slowly drained from the regulator on the bottle for several minutes afterwards). The outlet SF_6 concentration remained at 10.6 ppb for more than 1 hour until 137 hrs when it began to fall to a new steady state concentration of 9.2 ppb which it reached at 1142 hrs. It remained at this concentration until it began a steady decline to zero at 1207 hrs. The lowering of the steady state concentration from 10.6 ppb to 9.2 ppb has nothing to do with the turning off of the SF_6 supply since it would have taken about 48 minutes for the first effects of this to become noticeable at the outlet. This change in concentration must therefore be attributable to a change in the volume airflow through the stope, in this case an increase in the flow. Apart from this one change in flow the airflow remained steady from the start of the injection to about 1120 hrs and from equation 1 we can calculate its value:

$$\dot{v}\ (SF_6 \text{ flow rate}) = 0.765\ ml.s^{-1} = 0.0765 \times 10^{-6}\ m^3.s^{-1}$$
$$c\ (\text{outlet } SF_6 \text{ concentration}) = 10.6 \times 10^{-9}$$

$$Q = \frac{76.5 \times 10^{-9}}{10.6 \times 10^{-9}} = 7.22\ m^3.s^{-1}$$

The flow increased sometime after 1100 hrs to:

$$Q = \frac{76.5 \times 10^{-9}}{9.2 \times 10^{-9}} = 8.32\ m^3.s^{-1}$$

The change in airflow cannot be explained by any activities which occurred in the vicinity of the stope as none of the stope regulators were adjusted. The most likely explanation would be that a main ventilation door was either opened or closed somewhere in the section of the mine at or around 1100 hrs.

The Stope Residence Time and Volume

The average residence time of the air in the stope can be found from the continuous injection. The time taken from the start of the release of the SF_6 to reach half the steady state concentration is equal to the average residence time (4). The outlet concentration reached 5.3 ppb at approximately 1033 hrs, 61 minutes after the lecture bottle valve was opened. Similarly, the time taken to fall from the steady state concentration once the SF_6 supply is turned off to half the steady state concentration, also gives the average residence time (4). The outlet concentration fell to 4.6 ppb at 1217 hrs, 55 minutes after the SF_6 flow into the stope was stopped. From the two values of airflow and their corresponding residence time we can calculate the stope volume from the following relationship:

$$\text{Stope Volume} = t_{50} \cdot Q \qquad \text{Eq 3}$$

Table 2 - Results obtained from continuous injection into Stope 8260

Approx. Time (hrs)	Airflow ($m^3.s^{-1}$)	Average Residence Time (seconds)	Stope Volume (m^3)
0930 - 1100	7.22	3660	26425
1100 - 1230	8.32	3300	27456

Table 2 contains the results obtained from the continuous injection. The calculated values for the volume of the stope compare well with a volume estimation made from a large-scale surveyors plan of 24,730 m^3.

RESULTS OF PULSE INJECTION

Comparisons of Curve Shapes

Figures 3 to 7 show the computer corrected curves measured at the stope outlet during the five pulse injections (curve numbers 8260B - 8260F). These curves show the SF_6 concentrations measured in the exhaust air from Stope 8260 plotted against the elapsed time since the release of the tracer gas. Also shown on the Figures are the t_{25}, t_{50}, t_{75} times and the area

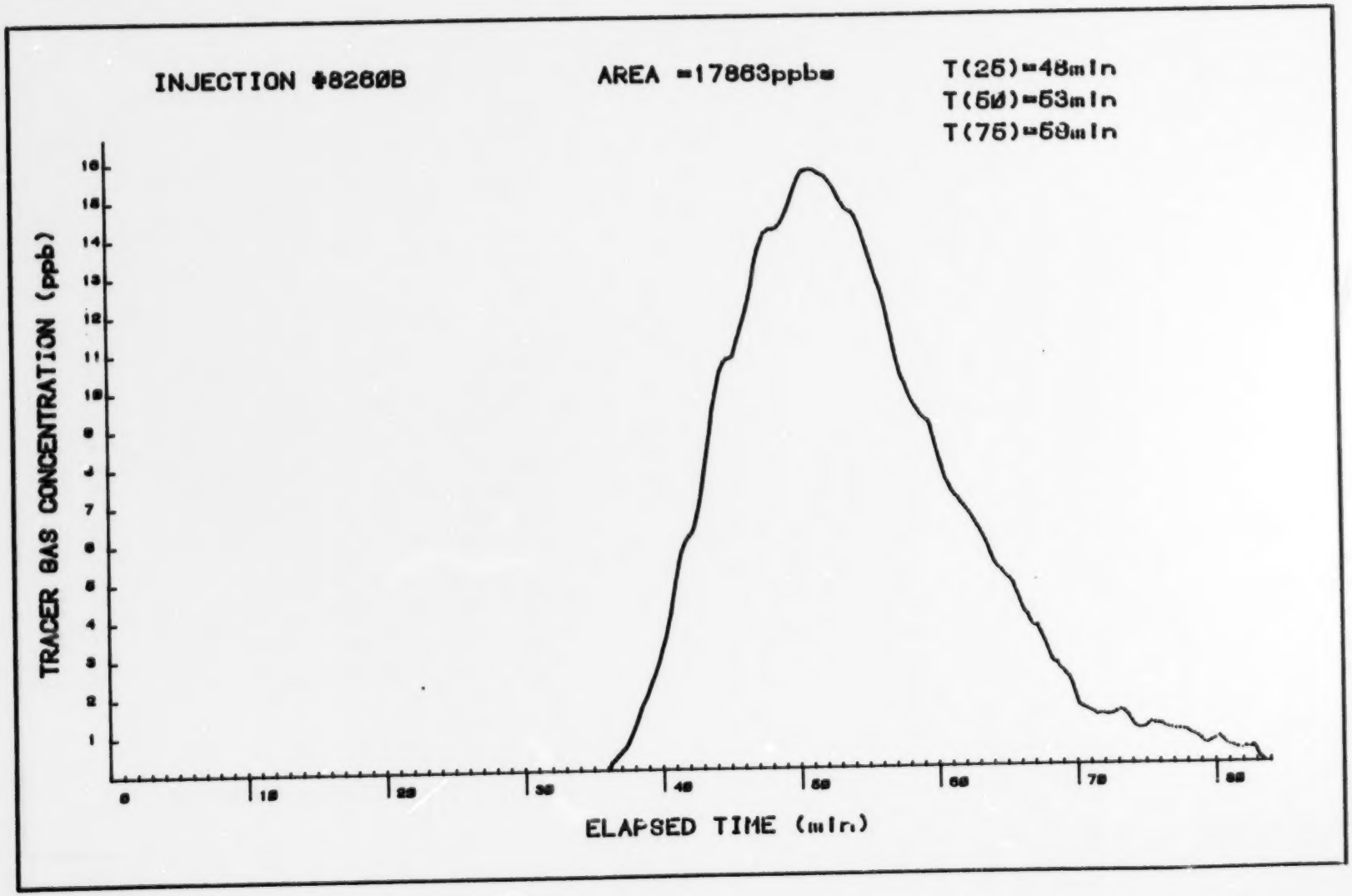

Figure 3 - Concentration/time curve for injection 3260B

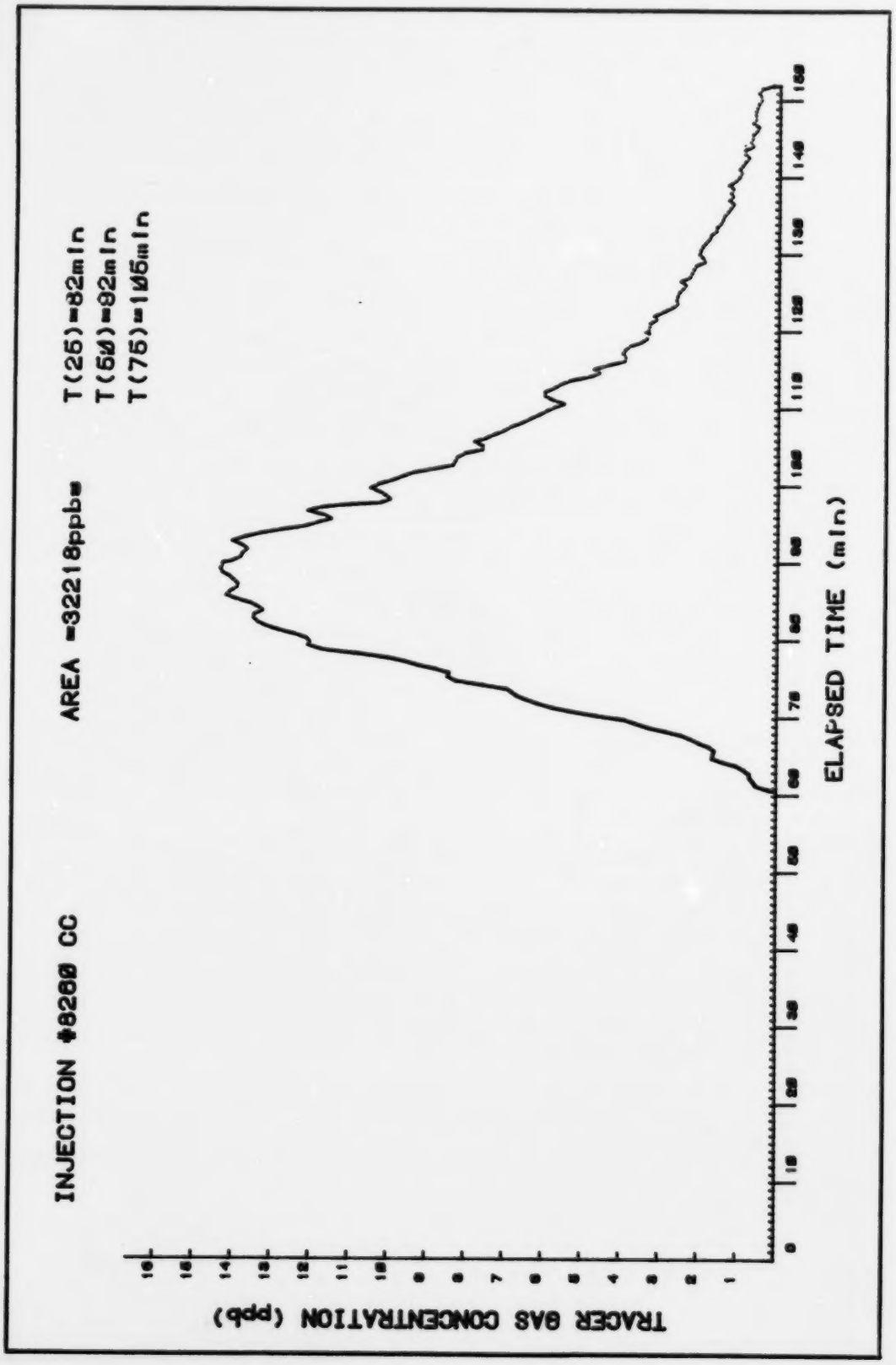

Figure 4 - Concentration/time curve for injection 8260CC

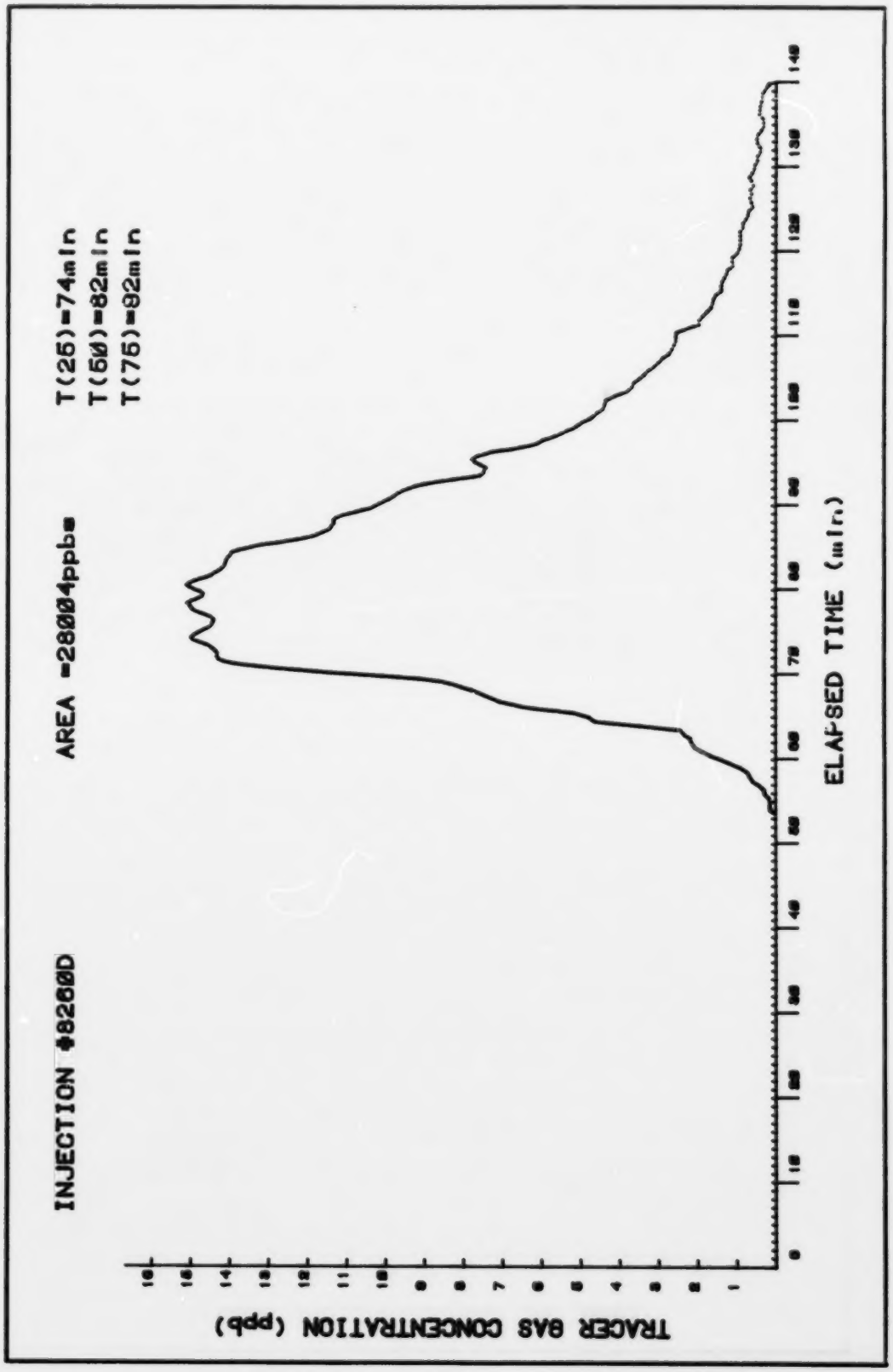

Figure 5 - Concentration/time curve for injection 8260D

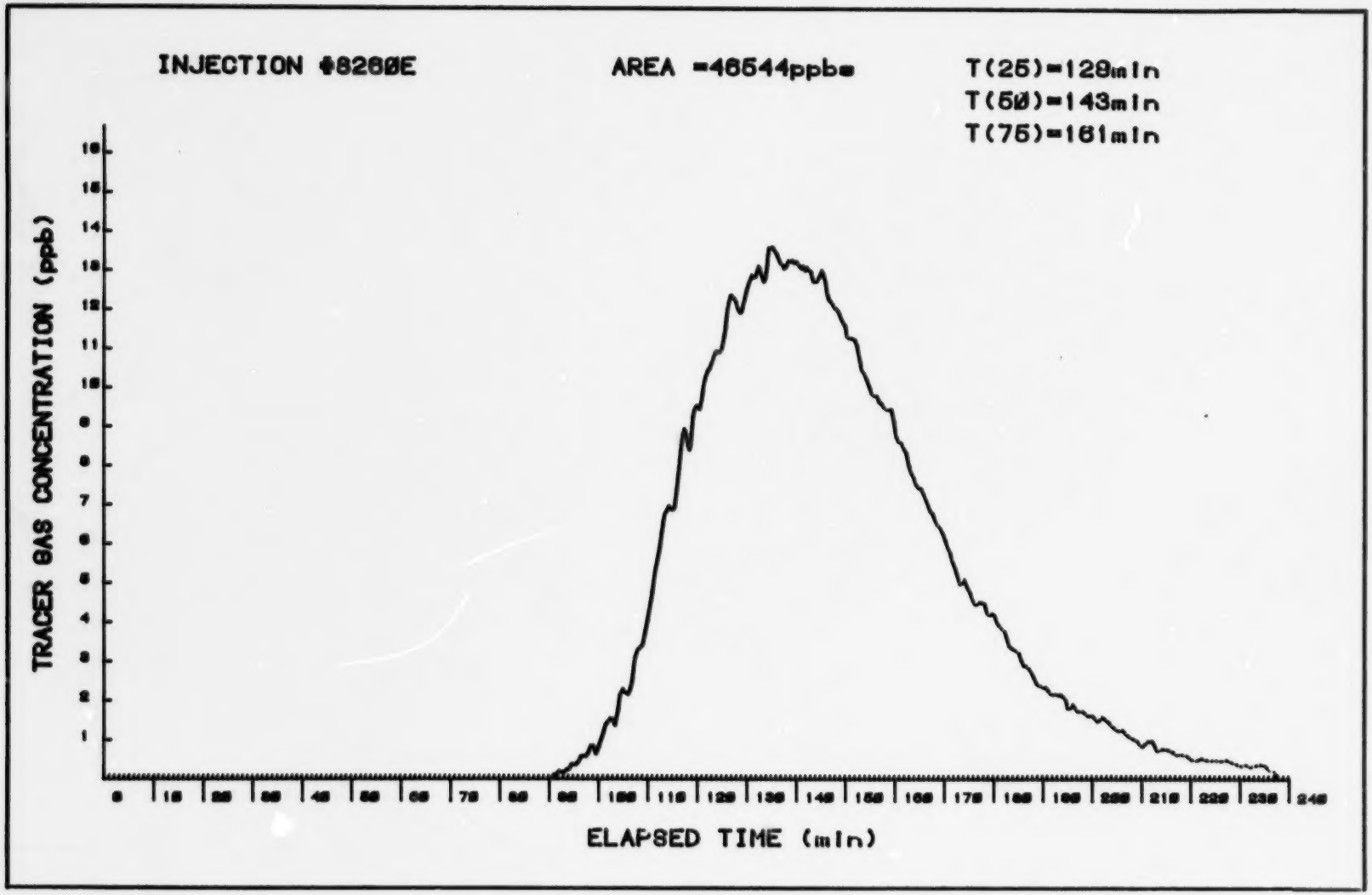

Figure 6 - Concentration/time curve for injection 8260E

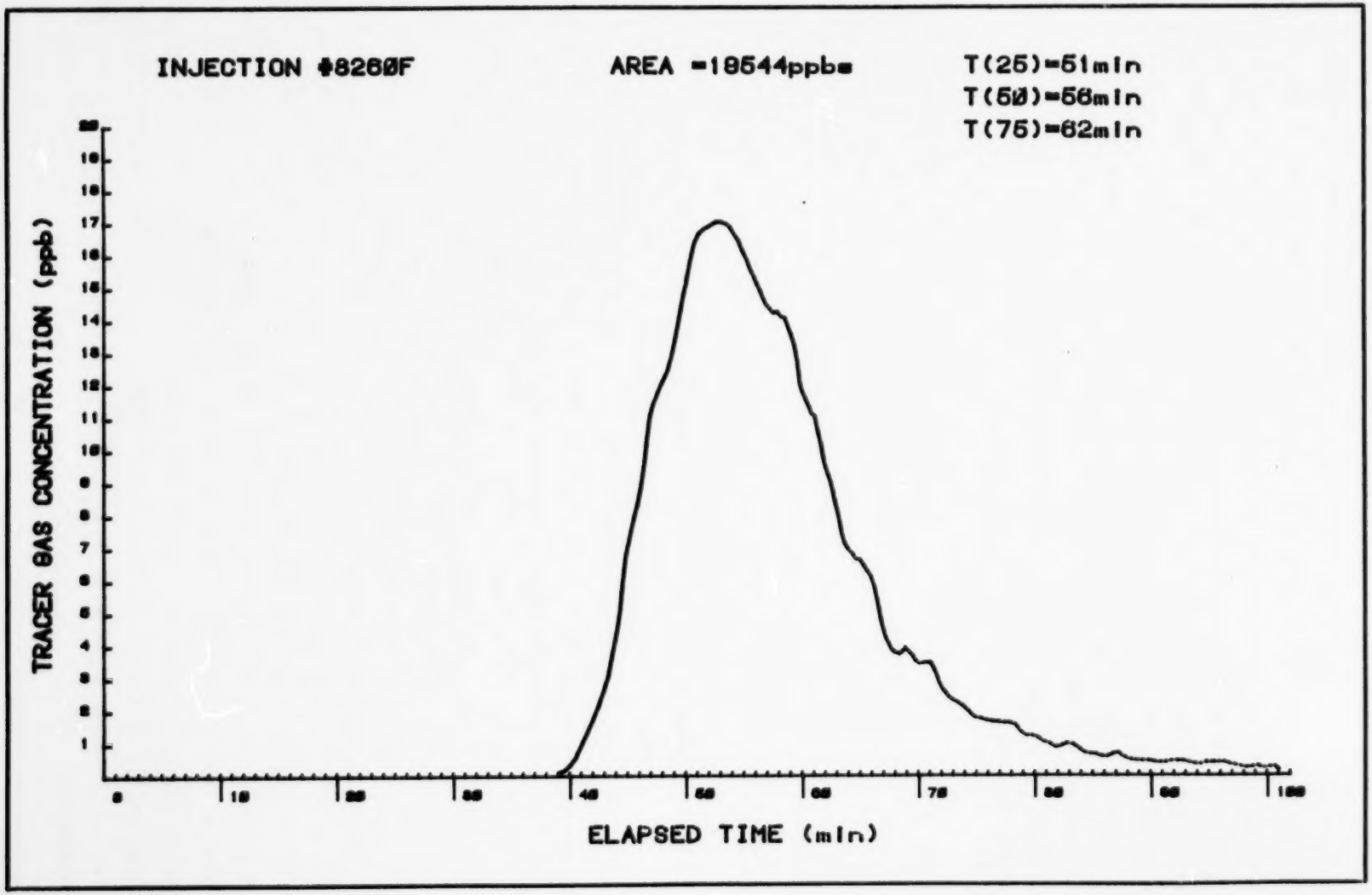

Figure 7 - Concentration/time curve for injection 8260F

under the curves (units of ppb.s). Curve 8260CC has a double suffix because it has been modified to take into account the smaller volume of SF_6 used for this injection. The curve shown has had all its concentrations multiplied by 50 percent, and consequently its area also, so that the curve shown is representative of a 150 ml release not a 100 ml. This modification was done to allow Figure 8 to be drawn which shows all of the curves drawn together on the same axes. This allows comparisons between the curves to be made.

When the curves are all drawn together it becomes apparent that some of the curves are similar in shape and from Figure 8 it seems that they could be broadly catagorised into three groups:

1) Curves 8260B and 8260F form one group. They have the same shape and attained their maximum concentrations within a few minutes of each other. The area under the curves is also very similar (17863 ppb.s and 19544 ppb.s) indicating that the airflows through the stope were also.

2) Curves 8260CC and 8260D form the second group. Like the first these curves have similar shapes, elapsed times to peak heights and areas (32218 ppb.s and 28004 ppb.s). The shapes of these two curves are so similar that even smaller subpeaks near the major peak and along the tail of the curves are seen in both, whereas they are not readily noticeable in the other three.

3) Curve 8260E (area of 46544 ppb.s) is in a group all by itself.

The grouping of the curves would seem to be dependent on the residence time (and hence the airflow) inside the stope. However, if all the curves in Figure 8 are modified by multiplying their x and y scales to bring the major peaks into alienment, then we get the curves shown in Figure 9. These curves are all very similar in shape and area. The same subpeaks can now be seen in all of the curves, which would suggest that the airflow distribution throughout the stope was identical for each of the injections despite the different airflows. The only difference between the five curves is the lateral dispersion which makes the features of the curves appear different.

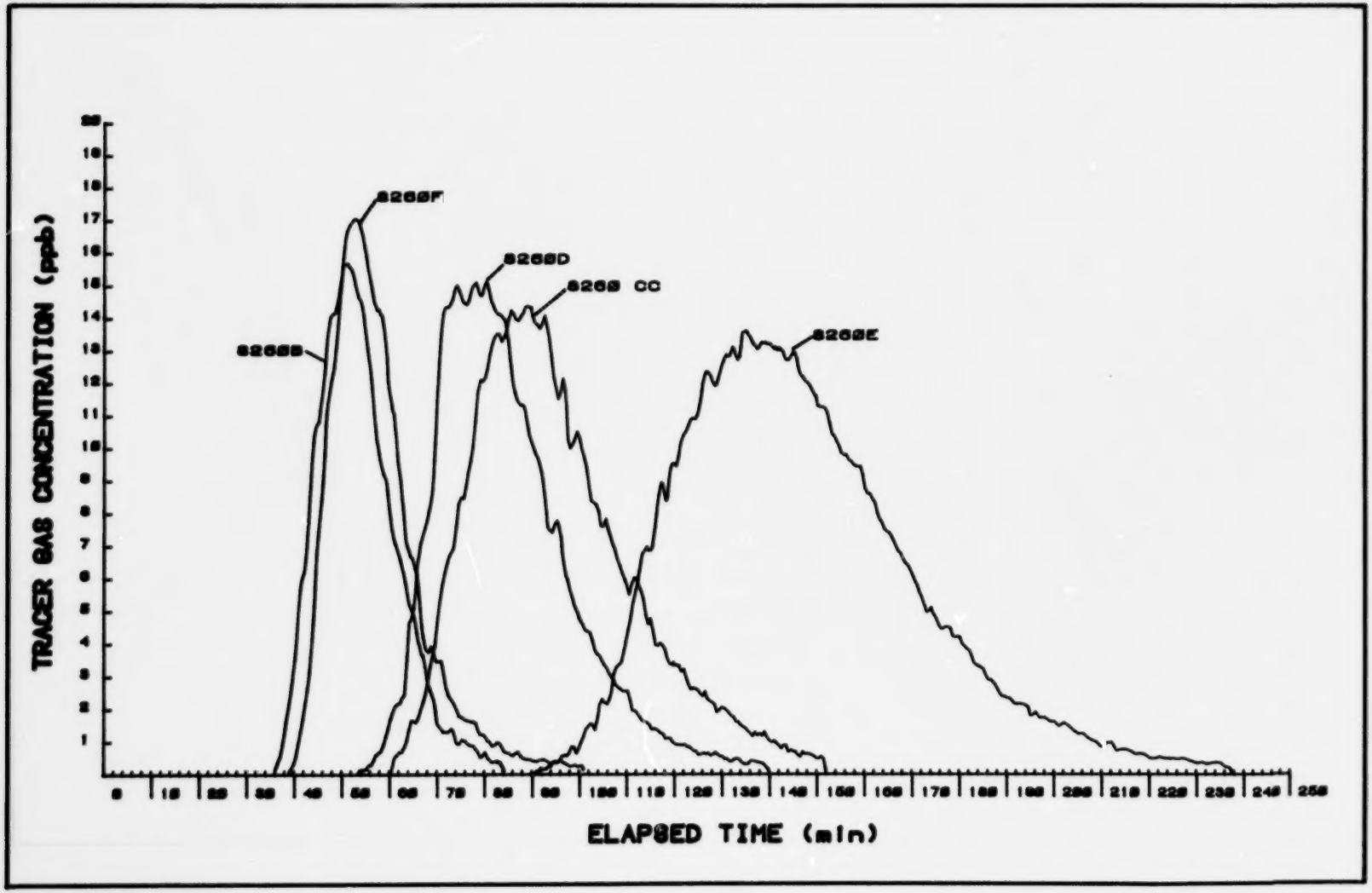

Figure 8 - Concentration/time curves for all pulse injections

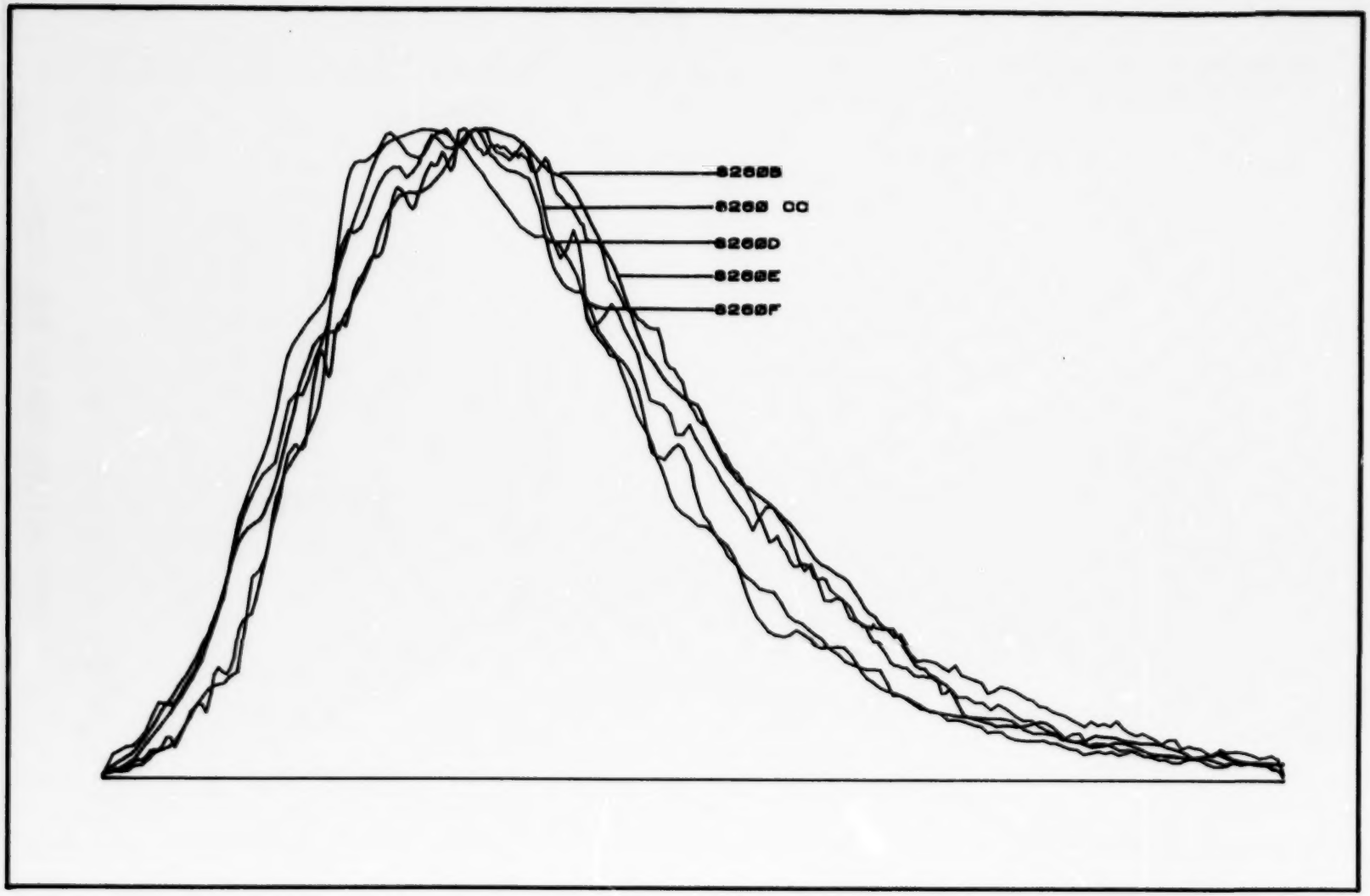

Figure 9 - Comparison of pulse injection concentration/time curve shapes

The general shape of the curves shown in Figure 9 is probably unique to Stope 8260 and could only be recreated in another stope if it had precisely the same internal geometry.

Stope Airflows

The airflows through the stope are calculated from the area under the curves as given by equation 2. These were:

Table 3 - Airflows in Stope 8260 during pulse injections

Curve Number	Area Under Curve (ppb.s)	Airflow ($m^3.s^{-1}$)
8260B	17863	8.40
8260CC	32218	4.66
8260D	23004	5.37
8260E	46544	3.22
8260F	19544	7.68

Stope Residence Times and Volume

The percentage removal curves in Figures 10 to 14 were developed from the concentration versus time curves. They show the cumulative percentage of the volume of tracer gas removed from the stope versus the elapsed time since it was released. Figure 15 shows all these curves plotted on the same axes. It has been previously shown (4) that the shape of these curves is the same as a concentration buildup that would be recorded from a continuous injection under the same conditions. And, as a consequence, the t_{50} time from these graphs (the time to remove 50 percent of the gas) equals the average residence time of the air inside the stope.

Table 4 contains the average residence times for the five pulse injections and also the stope volume calculated as the product of the residence time and the airflow.

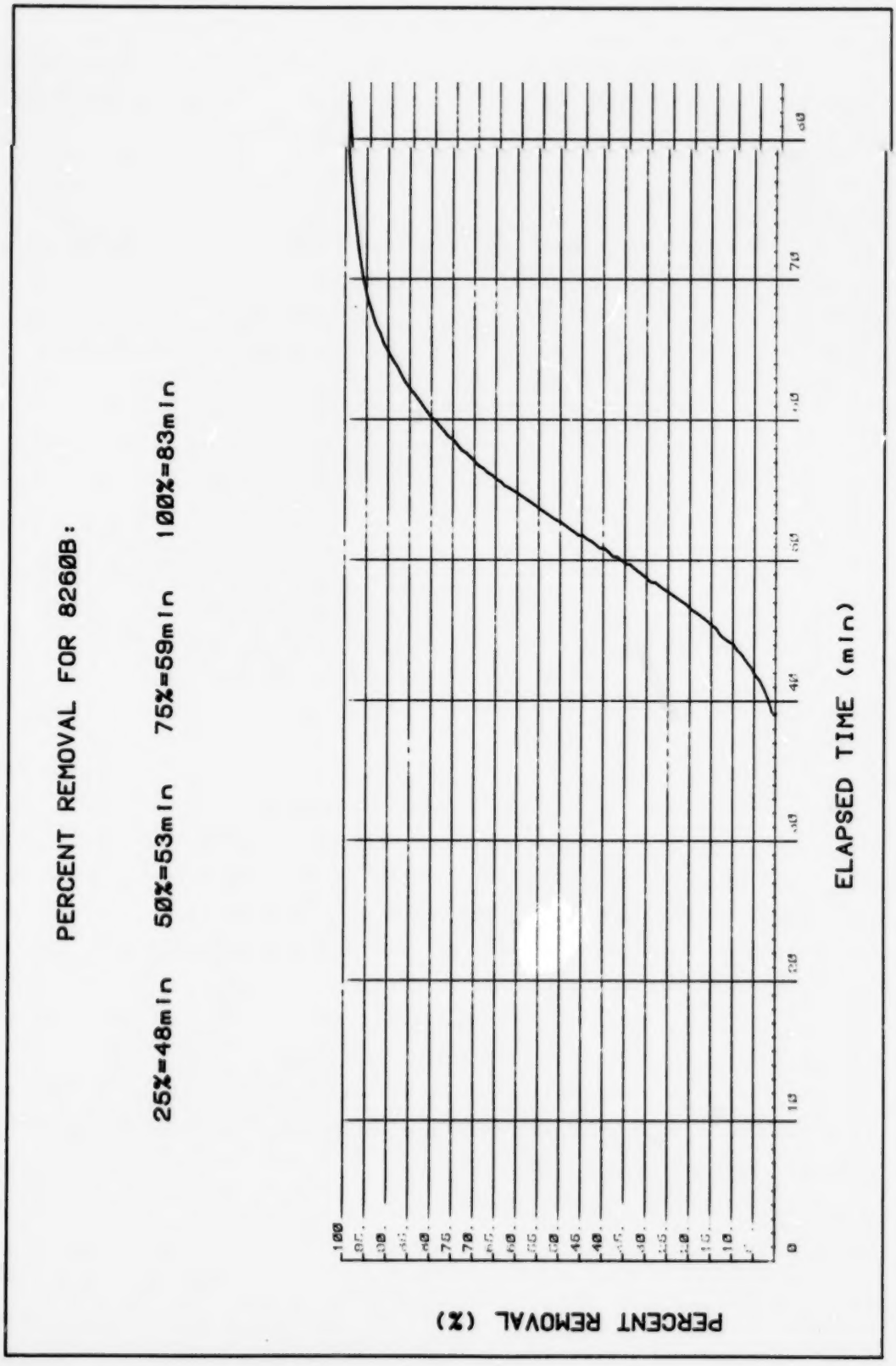

Figure 10 - Percentage removal curve for injection 8260B

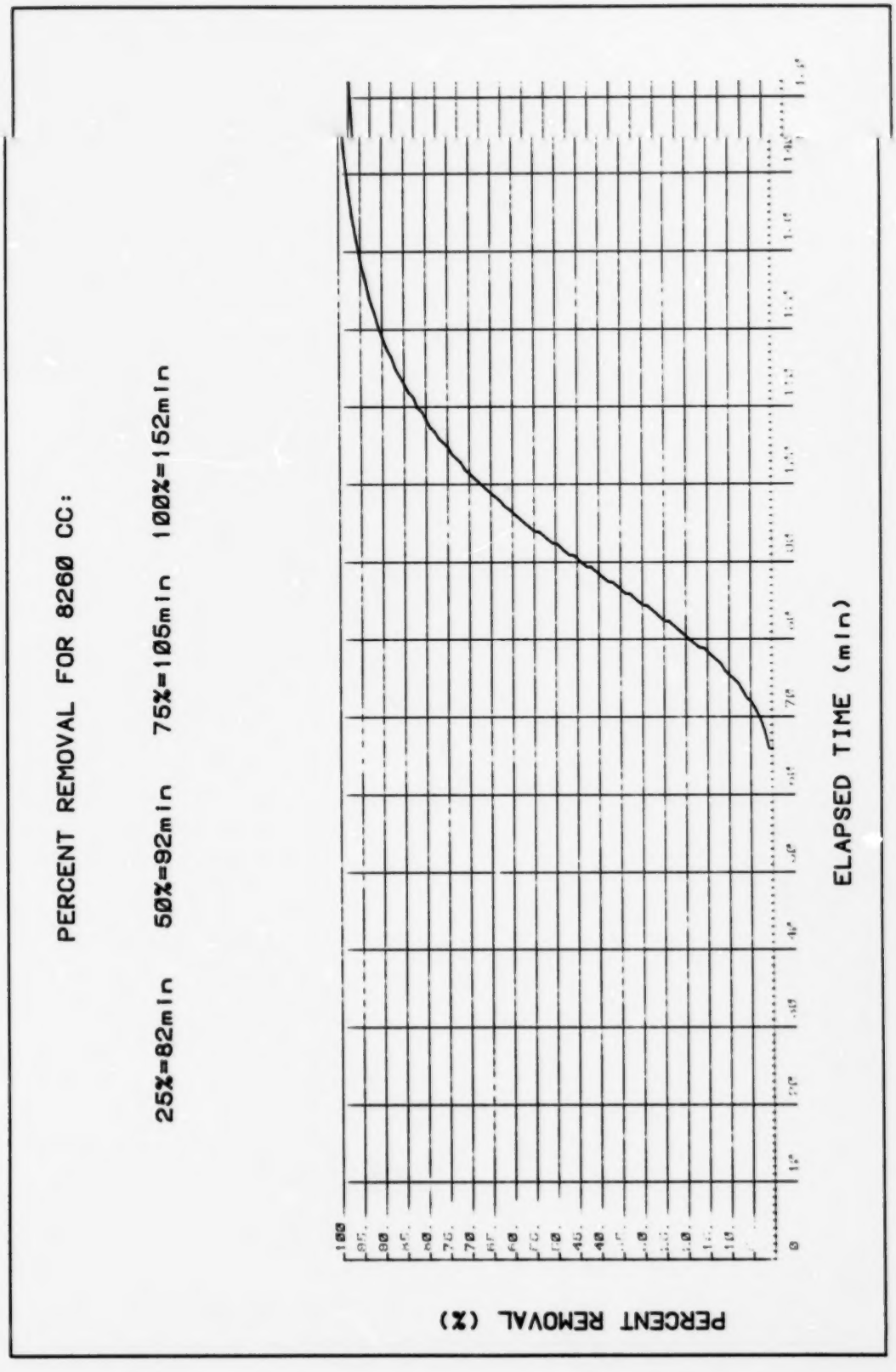

Figure 11 - Percentage removal curve for injection 8260CC

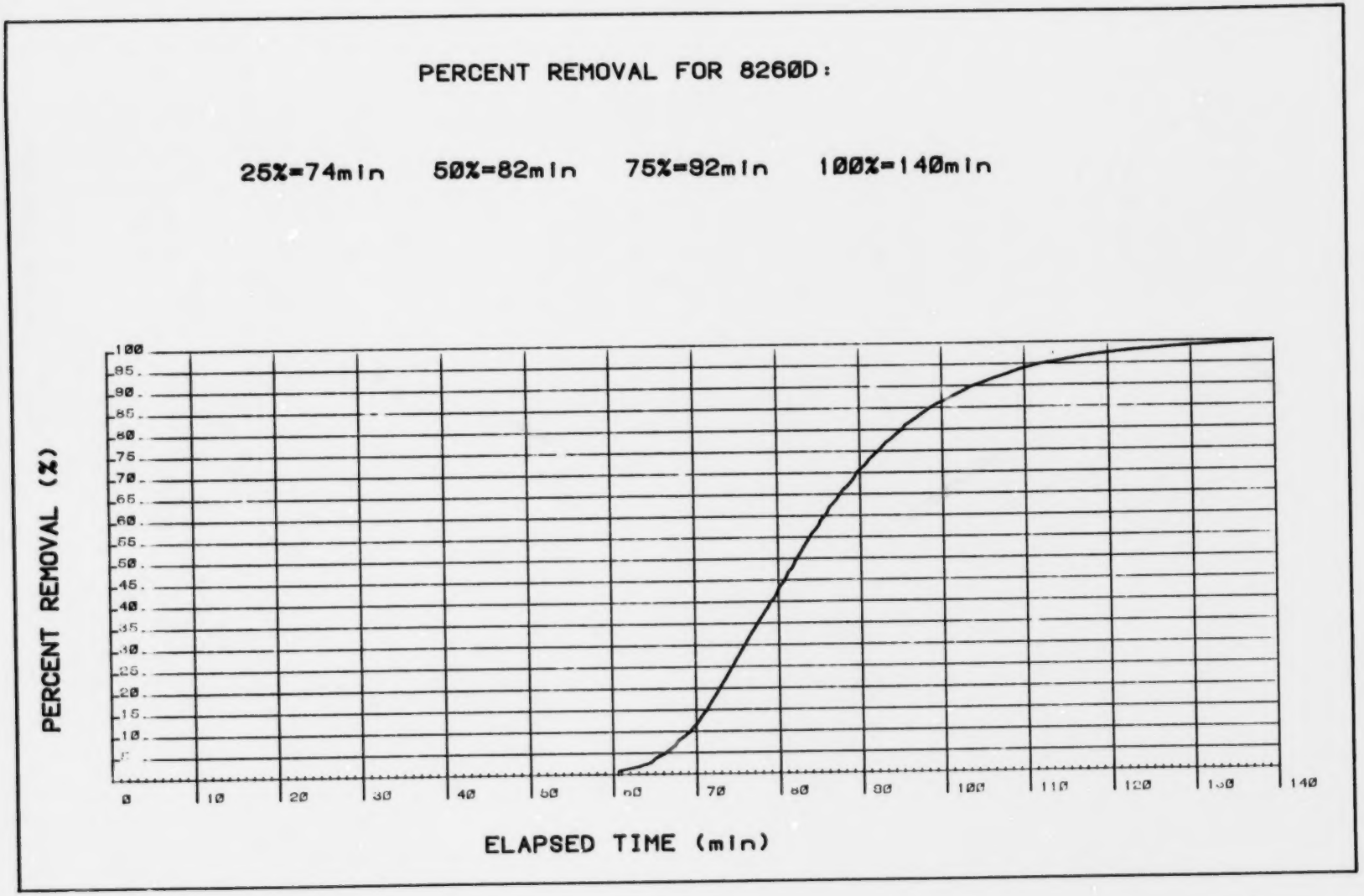

Figure 12 - Percentage removal curve for injection 8260D

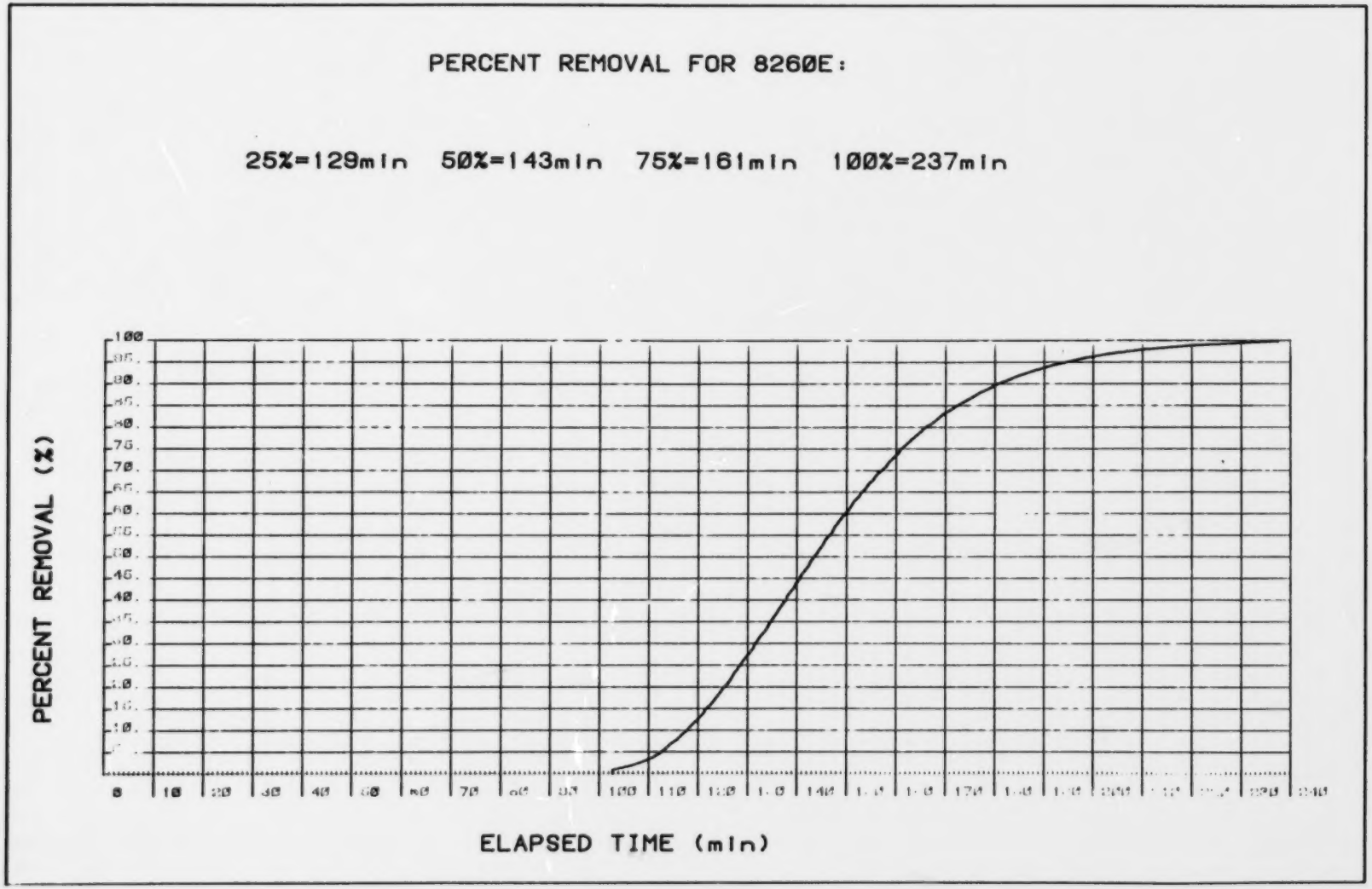

Figure 13 - Percentage removal curve for injection 8260E

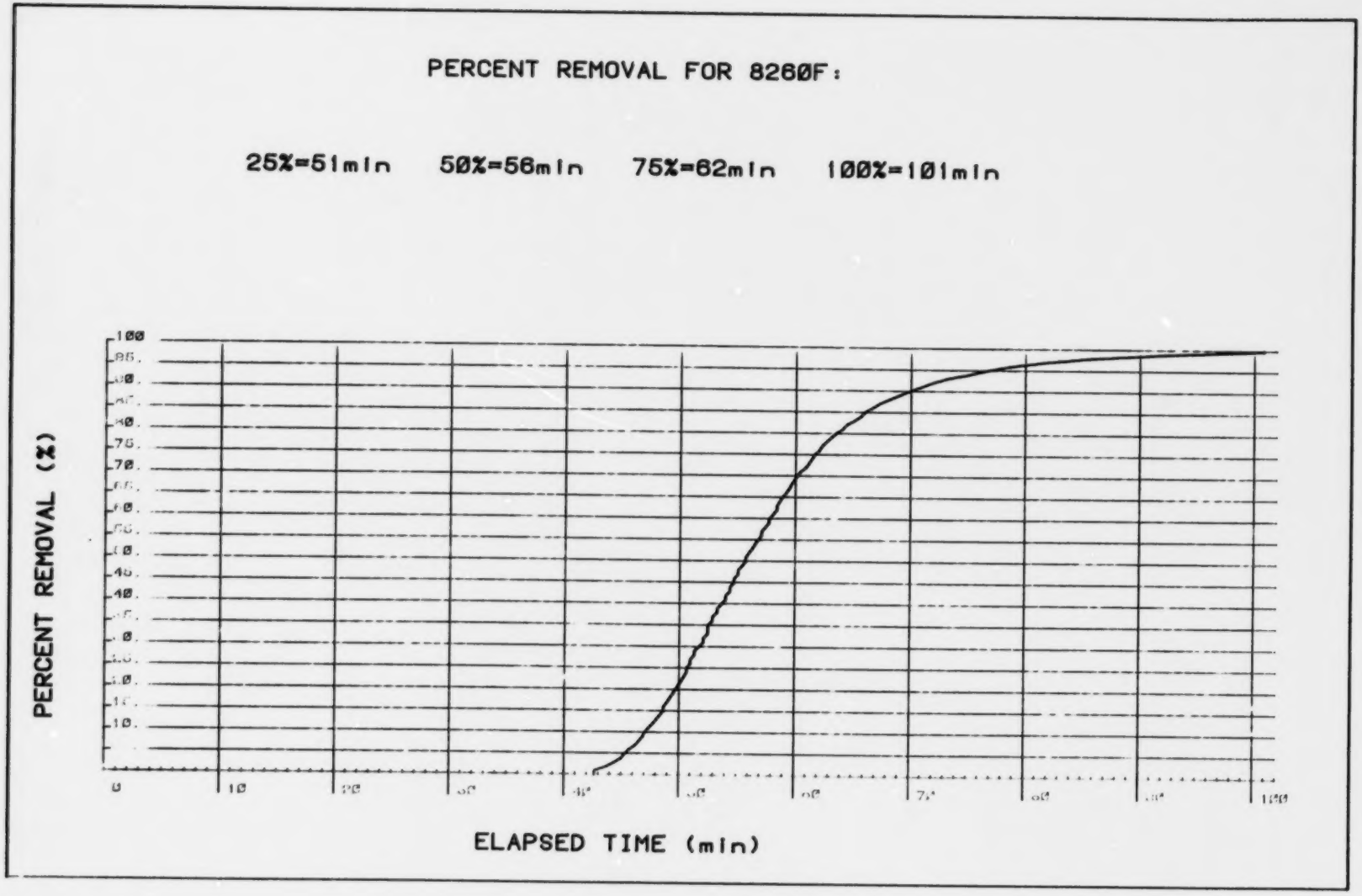

Figure 14 - Percentage removal curve for injection 8260F

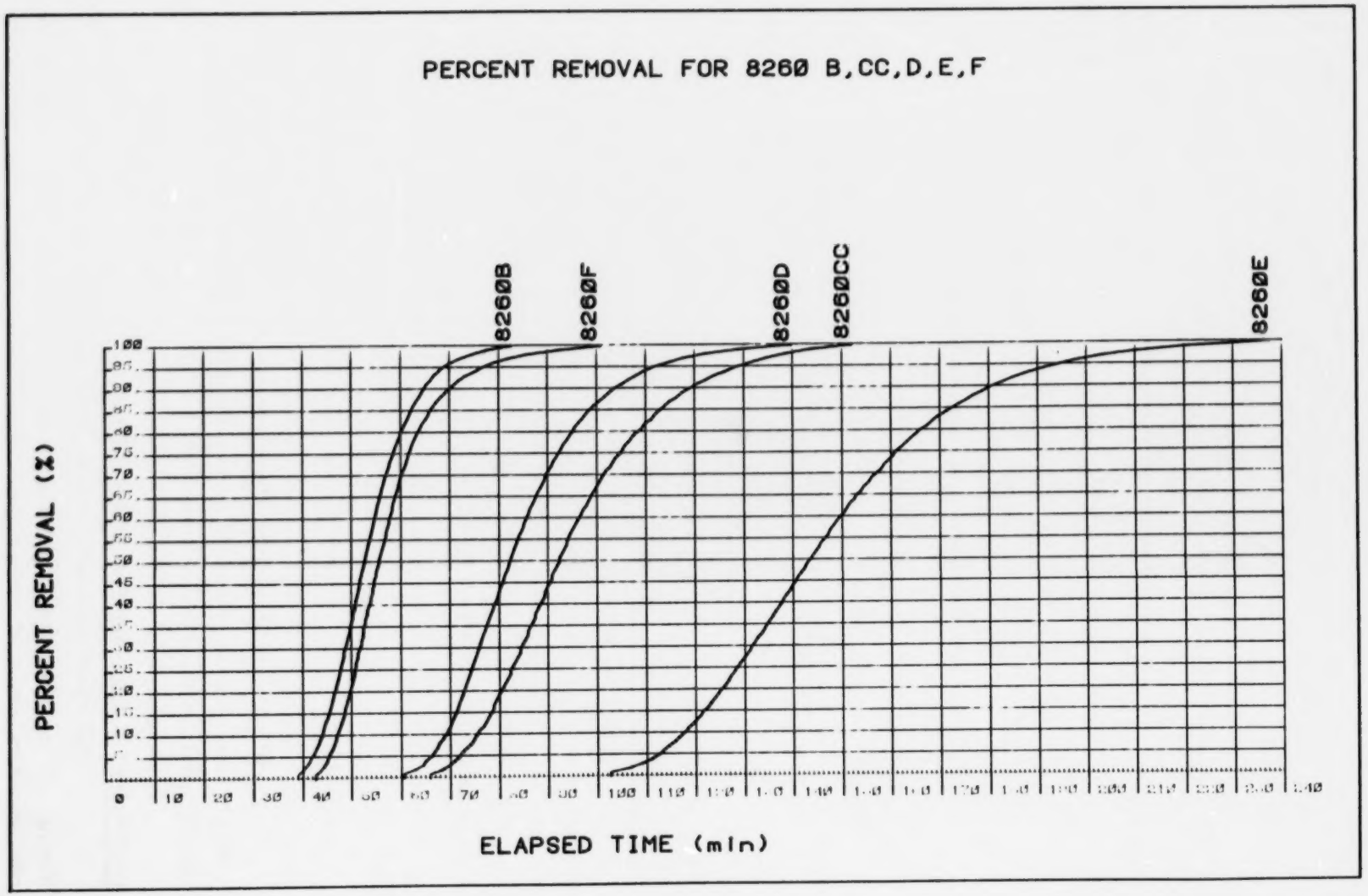

Figure 15 - Comparison of percentage removal curve for pulse injections

Table 4 - Average residence times and stope volumes obtained from the pulse injections

Injection Number	Average Residence Time (t_{50}) (mins)	Stope Volume (m^3.)
8260B	53	26703
8260CC	92	25700
8260D	82	26353
8260E	143	27651
8260F	56	25788

The five calculated values of the stope volume are all in close agreement. The average of these (26439 m^3) agrees well with the two values obtained from the continuous injection (26425 m^3 and 27456 m^3).

ANALYSIS

RELATIONSHIP BETWEEN RESIDENCE TIME AND AIRFLOW

From the pulse injections and the continuous injection we have average residence time values for seven different stope airflows. Figure 16 is a graph of these seven data points plotted as the residence time versus the airflow. A line has been drawn onto Figure 16, this is found from a rearrangement of equation 3:

$$Q = \frac{V_s}{t_{50}} \qquad \text{Eq 4}$$

where V_s is average of the calculated stope volumes (26582 m^2)

All the data points lie close to the theoretical line confirming that for the range of airflows tested the average residence time was directly proportional to the airflow through the stope.

COMPARISON OF PULSE AND CONTINUOUS INJECTION

The field survey in Stope 8260 provided an opportunity for comparing the two techniques available for this study, namely the pulse and continuous releases of tracer gas.

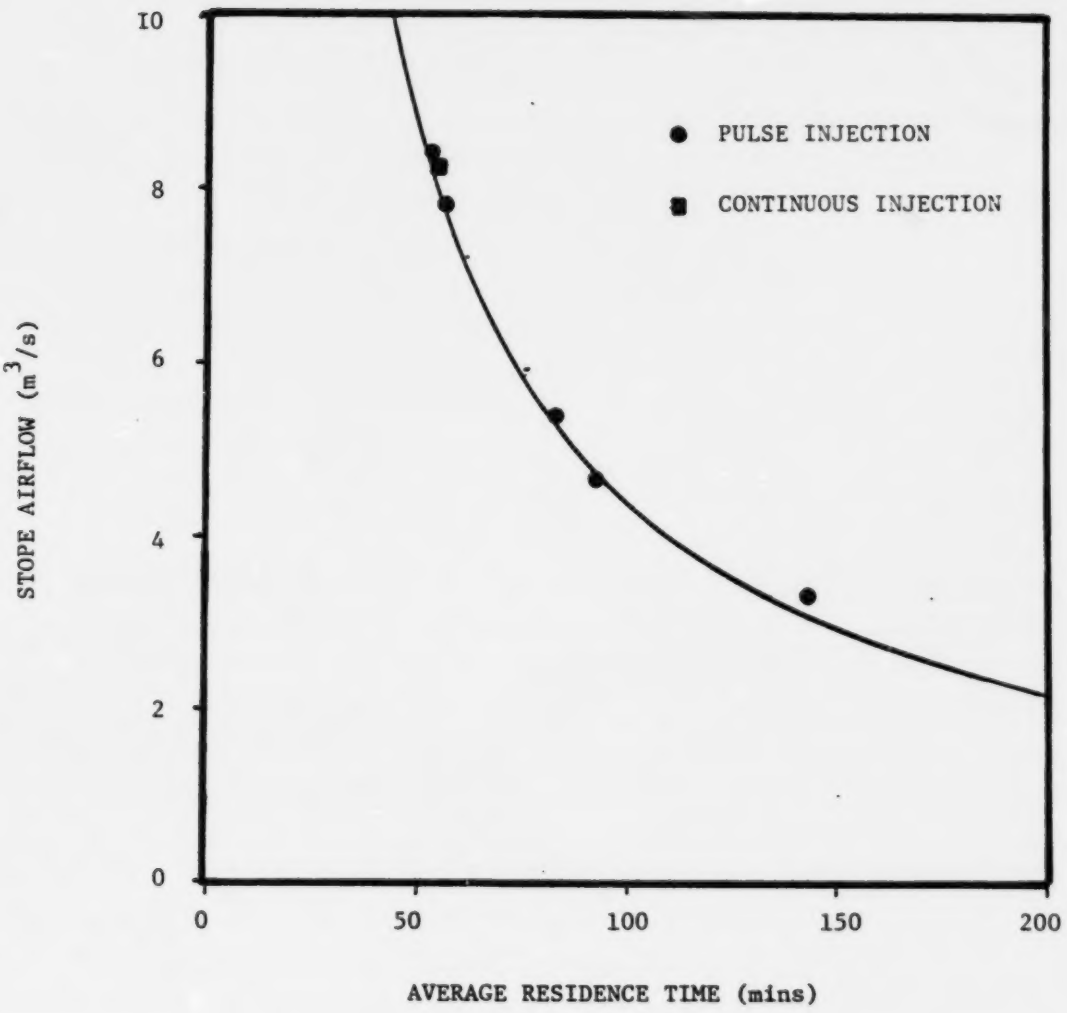

Figure 16 - Stope residence time versus airflow

The continuous injection of tracer gas had one advantage over the pulse injection in that it did allow an evaluation of the airflow stability in the stope. This was not possible using the pulse release of gas. Other than this, both techniques provided the same level of information (i.e. residence times, airflow and stope volume). It is arguable that the curves produced by the pulse injection are easier to interpret, in that it is much easier to determine the t_{50} time from a pulse injection curve than the elasped time from the start of a continuous injection to the movement at which the half steady state concentration is reached. However, the real advantages of the pulse injection technique are that it is quicker and easier to do. Two pulse injections could have been done in Stope 8260 for the time it took to complete the continuous injection and it is easier to dispense a measured volume of tracer gas from the syringe than a steady continuous flow from a lecture bottle.

So it is the opinion of the authors that for this application and others where the necessary information can be obtained from a pulse injection that it is a superior technique to a continuous one. The limitation is that an analytical instrument is needed to detect the gas underground so that the technique can be optimised.

COMPARISON OF PULSE INJECTION TRACER GAS TECHNIQUE AND CONVENTIONAL ANEMOMETRY

During the field survey the airflow was also monitored by conventional anemometry instruments. This included using:

1) thermal anemometers, Airflow Developments Limited TA 3000T and TA 400, and a vane anemometer, Airflow Developments Limited EDRA 5, to traverse the intake regulator openings; and
2) the vane anemometer, EDRA 5, and a pitot tube micromanometer configuration, Air Instrument Resources Limited MP3KDS, with data loggers, Grant Instruments SQ8, for continous recording.

Velocity traverses were taken at the intake regulator for each pulse injection and the airflow determined. Figure 17 depicts the compared results of tracer gas and anemometer derived airflows. Although the two methods show a high degree of linear correlation, 0.995, the regression line shows the shortcomings of the conventional method, it being responsive only when airflow is in excess of 3 m^3/s.

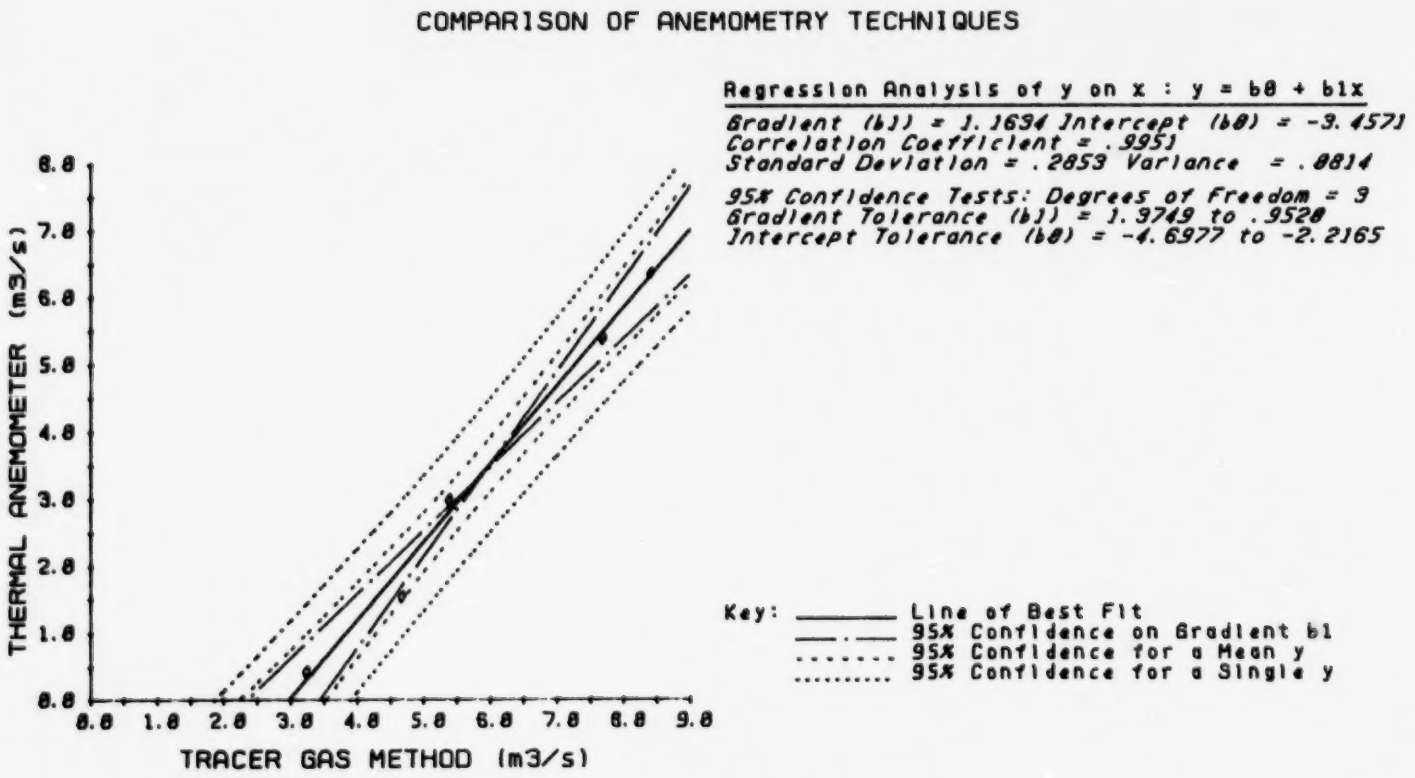
COMPARISON OF ANEMOMETRY TECHNIQUES
Regression Analysis of y on x : y = b0 + b1x
Gradient (b1) = 1.1634 Intercept (b0) = -3.4571
Correlation Coefficient = .995
Standard Deviation = .2853 Variance = .0814
95% Confidence Tests: Degrees of Freedom = 9
Gradient Tolerance (b1) = 1.3749 to .9520
Intercept Tolerance (b0) = -4.6977 to -2.2165
Key: Line of Best Fit
95% Confidence on Gradient b1
95% Confidence for a Mean y
95% Confidence for a Single y
THERMAL ANEMOMETER (m3/s)
TRACER GAS METHOD (m3/s)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

Figure 17 - Comparison of tracer gas and anemometry determined airflows

In this study, problems with measurement of the airflow by conventional means were envisaged as the regulator effectively operated at an orifice and the measurements were taken at a vena contracta zone. This is normally not advisable and the results demonstrate this. The open area of the regulators was also difficult to determine because of leakage paths and obstructions.

Conventional measurement of air on the return end of the stopes was also impractical as the opening exceeded 15 m^2 and would only contain air velocities between 0.2 to 0.5 m/s for the full range of regulator openings.

Figure 18 shows the continuous airflow traces during four of the pulse injections as derived from the recording anemometers. The original records of a reading every 10 seconds have been reduced to 5-minute averages.

The results of the vane anemometer and the pitot tube/micromanometer were corrected for positional velocity as compared to the traverse averaged velocity. Then the regression analysis data were used to calibrate the anemometers responses.

The four traces in Figure 18 show the consistency of flow during the injections for the maximum flow, the average flow and standard deviation were 8.5 ± 0.4 m^3/s, that is less than 5% variation. The deviations were less in lower flows, and the two lowest traces lack detail due to the poor sensitivity of the anemometers at these flows.

CONCLUSIONS

The prototype instrument developed for rapid sequential analysis of SF_6 in underground environment performed very well in this field trial. Further modifications need to be made to make the instrument more portable, but the general configuration appears to be sound.

The availability of a rapid sequential analysing gas chromatograph underground increases the versatility of the tracer technique. The pulse injection technique has been shown to be more flexible and easier to use than the continuous injection. The true value of the pulsed injection should become more apparent with the availability of other tracer gas which can be analysed by the same gas chromatograph.

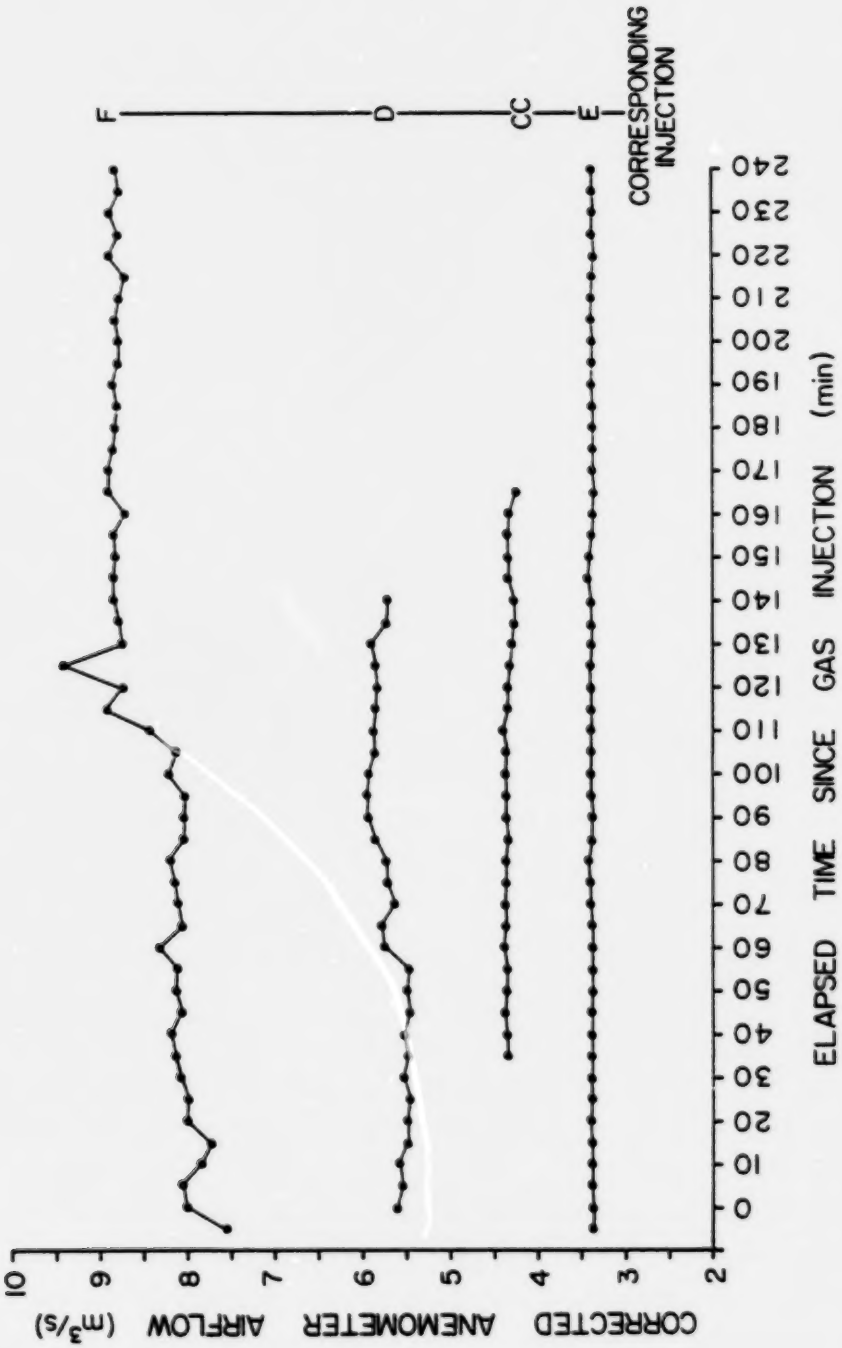

Figure 18 - Anemometer derived airflows during the pulse injections

The experiments conducted in Stope 8260 not only allowed the instrument to be field tested but also produced verification of the relationship between the stope airflow and residence times inside the stope. This information should further the research efforts of scientists investigating radon daughter decay in such stopes.

In large airpaths where the velocity is 0.5 m/s or less, and in areas of rapidly changing cross-sectional area such as regulators, the measurement of airflow by conventional anemometry method can be extremely difficult and/or inaccurate. In these instances the use of a tracer gas technique is extremely beneficial and accurate.

The anemometers and data loggers did show potential in easily being able to monitor changes in airflow, but were not ideally suited to this application.

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